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BAK-14 RETRACTABLE HOOK-CABLE SUPPORT SYSTEM COLD-WEATHER TESTS AT GALENA, ALASKA

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27 AUGUST 1974

Final Report for Period 15 through 20 January 1974

Prepared for

Commanding Officer
Naval Air Engineering Center
Philadelphia, Pa. 19112

NATF-EN-1132

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HOOK-CABLE SUPPORTS
SHOREBASED AIRCRAFT ARRESTING GEAR/SYSTEM

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The BAK-14 retractable hook-cable support system was designed for use with aircraft arresting systems on Air Force/Civil joint-use airfields. In the raised position, the BAK-14 supports the aircraft arresting-hook cable above the runway surface for engagement of arresting-hook-equipped aircraft; in the lowered position, the runway surface is clear and the BAK-14 offers no interference to the operation of lightweight civil aircraft. These tests were conducted to

Continued on next page.

BLOCK 20 CONTINUED

determine the effects of natural low-temperature conditions on the functional and dynamic operation of the BAK-14. The areas of special interest were the ability of the support block to withstand aircraft main-gear trample and arresting-hook impact, and the ability of the system to cycle 100 times. Tramples and arrestments were conducted with the F-4E aircraft under -15° F to -24° F ambient temperature conditions. The system sustained negligible damage from the aircraft tramples, but was inoperable as a result of the cumulative damage caused by the six arrestments. Under the low ambient temperatures, the supports were not pliable. All 14 blocks of the system were partially to fully separated from their bases. Support-block latch mechanisms were damaged. The 100-cycle test was completed under -33° F to -36° F ambient temperatures. During this test, several support latch mechanisms malfunctioned and required adjustment. Test results indicated that the BAK-14 is not suitable for operation at low ambient temperatures.

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I INTRODUCTION

A. BACKGROUND

1. The BAK-14 retractable hook-cable support system is designed for use with aircraft arresting systems to satisfy the requirements of military and civil aircraft operations on Air Force/Civil joint-use airfield runways. The system is capable of raising the arresting-system hook cable above the runway surface for the engagement of hook-equipped aircraft, and of lowering the hook cable below the runway surface to prevent interference and damage during rollover of lightweight aircraft *(rollover is defined as to traverse a lowered/retracted hook cable)*.

2. This test program was conducted to determine the effects of natural low-temperature conditions on the functional and dynamic operation of the BAK-14 retractable hook-cable support system. It was necessary to obtain this information in order to evaluate the suitability of the system for eventual operational use in Alaska.

3. The Air Force/Civil joint-use airfield at Galena, Alaska, was selected by the Air Force for the initial installation and test of the BAK-14 in that State. The Galena airfield test-site location was selected because of the local requirement for the system and the low-temperature climatic conditions which are typical in Alaska and necessary for the tests. The Air Force contractor installed the BAK-14 at Galena in September 1973. Air Force arresting-system personnel maintained the system on inactive status until the start of these tests.

4. The test program was conducted for the Air Force by the Navy test team in accordance with reference (a) on the main runway of the State of Alaska Airport, Galena, Alaska, from 15 to 20 January 1974. It consisted of two parts as follows:

a. A functional inspection to assure the system was ready for test.

b. A dynamic test, using the BAK-12 aircraft arresting system, which consisted of F-4E aircraft tramples and arrestments, and 100 consecutive cycles of the BAK-14 system *(trample is defined as to traverse a raised and tensioned hook cable)*.

5. Because of the limited time available, no attempt was made to conduct these tests under specific temperature or weather conditions for data purposes. The weather conditions existing at Galena during the period scheduled for the tests were accepted. The results of these tests are presented in this report.

Ref: (a) NAVAIRSYSCOM msg 022118Z Jan 1974: Cold Weather Testing of BAK-14 Galena Alaska

B. <u>TEST OBJECTIVES</u>: The areas of specific interest and for evaluation of the BAK-14 under low-temperature conditions were as follows:

1. The ability of the support blocks to withstand trampling by the aircraft main gear and impact with the aircraft arresting hook.

2. The ability of the system to cycle 100 times.

3. The time required to raise and lower the system.

4. Possible problems involved with installing the hook cable in the support blocks; tying the hook cable to the support blocks; replacing the support blocks; and adjusting the support-block latches.

C. <u>PREVIOUS TESTS</u>

1. The test and evaluation of several retractable hook-cable support systems, including the BAK-14 retractable hook-cable support prototype (Thurston-Erlandsen Corporation hook-cable support assembly) design and the early BAK-14 retractable hook-cable support system designs, is described in references (b) and (c) respectively.

2. Reference (d) describes the extent of the development effort which preceded the reference (e) tests in which the Air Force acceptance requirement for the BAK-14 of 76 consecutive successful engagements was realized.

Ref: (b) NAVAIRTESTFAC Report No. NATF-EI-108 of 31 Aug 1964: Evaluation of Retractable Pendant Supports for the Federal Aviation Agency
(c) Air Force Systems Command, Aeronautical Systems Division, Technical Report No. ASD-TR-69-9 of Aug 1969: BAK-14/F32 Retractable Cable Support System
(d) Air Force Systems Command, Air Force Flight Test Center, Technical Report No. FTC-TR-72-41 of Mar 1973: Testing of the BAK-14 Retractable Cable Support System
(e) NAVAIRTESTFAC Report No. NATF-EN-1128 of 22 Jan 1974: Evaluation of the BAK-14 Retractable Hook-Cable Support System

II CONFIGURATION AND DESCRIPTION

A. GENERAL DESCRIPTION

1. The BAK-14 hook-cable support system consists of rubber blocks which support and restrain the hook cable of the aircraft arresting system approximately 3 inches above the surface of the runway.

2. Each support block is mounted on a support arm contained in a covered metal box inserted in the runway. A steel trough is provided in the runway to accept the hook cable. Retraction of the support arm moves the support block down into the metal box and the hook cable into the metal box/steel trough. Thus, a flush runway surface is obtained when the system is lowered.

3. Retraction of the hook cable is accomplished by means of a pressurized pneumatic system. The hook cable is raised when the system air pressure is vented allowing the spring-loaded support arms to rise. The appropriate switching circuits are provided so that the airfield tower and the BAK-14 operating personnel on the runway may control the position of the hook cable in the up or down position.

4. When installed on a 150-foot-wide runway, the system includes 14 support blocks, 14 support boxes, 13 inter-trough sections, and 2 end-trough sections. The support blocks are located on 8-foot centers, with 7 supports on each side of the runway centerline. Thus, the system supports a hook-cable nominal length of 112 feet of the 153-foot-long cable on the 150-foot-wide runway that is available for ON- and OFF-CENTER arrestments.

5. The BAK-14 retractable hook-cable support system at Galena is installed at the existing Air Force BAK-12 emergency runway aircraft arresting-system installation. The arresting system is located 2,360 feet from the approach end of runway heading 250° on the 6,300-by-150-foot macadam-surfaced main runway. The support system is offset one foot to the right of the runway centerline as shown in Figure 1 below.

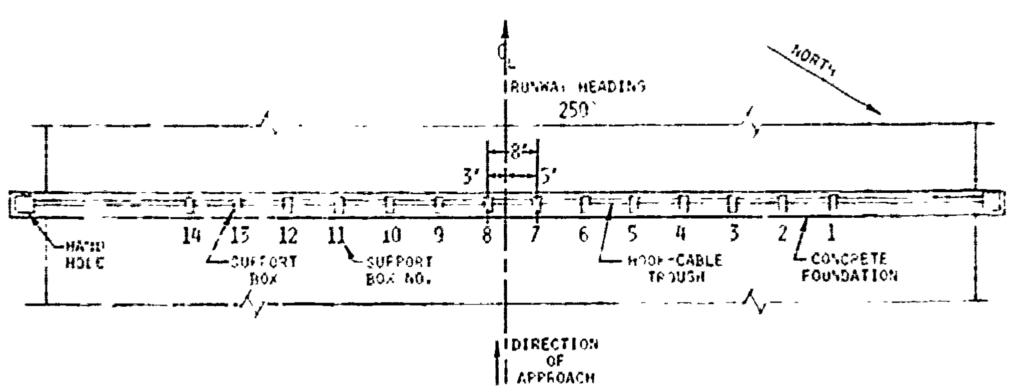


FIGURE 1 - SKETCH OF THE BAK-14 RETRACTABLE HOOK-CABLE SUPPORT SYSTEM

B. DETAILED DESCRIPTION

1. SUPPORT BLOCK, G&W *(Gulf & Western)* PN SK-D-250: The hook-cable support shown in Figure 2 consists of a neoprene rubber block that is molded with a metal frame in the base, and provided with a diagonal slot in the top for insertion and removal of the hook cable from the 1-1/4-inch-diameter retention hole in the block body. A shaft inserted through the frame base of the block and through the support arm, anchors the block to the arm and allows the block to pivot about the shaft. The cam plate rollers and extension springs necessary to guide the pivot motion of the block are attached to the base. The frame base of the block is also provided with a through hole to accept the nylon cord used for tying the support block to the hook cable.

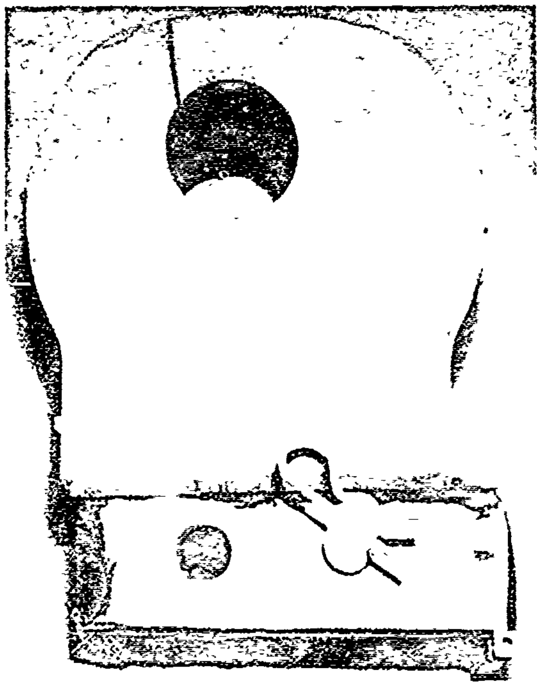


FIGURE 2 - SUPPORT BLOCK

2. SUPPORT BOX ASSEMBLY, G&W PN 52-E-768: The support box contains the operating means to raise and retract the support block. The support arm pivots on a shaft and swings the support block, which is pivoted on the end of the arm, in an arc. The combined pivoting motion of the arm and the block results in a horizontal linear distance of approximately 4-5/8 inches between full up position (3-inch nominal hook-cable clearance above the runway) of the block and full down position (hook cable in the trough) of the block. The 4-5/8-inch offset distance feature is designed to prevent missed engagements due to hook-cable entry into the trough during the cable dynamics resulting from aircraft-wheel trample. To lower the block, a compressed-air actuated cylinder contacts and applies a force against the offset yoke of the torsion-spring-loaded support arm and swings the arm down; simultaneously, the air cylinder also actuates the support block latches by means of a wire-rope shaft-link arrangement which releases the block from the full up position and allows it to pivot down. Release of air pressure permits the torsion springs to rotate the support arm and place the support block in the full up position, where it is automatically locked by the spring-loaded latches. Bearings on the support arm pivot shaft permit easy movement of the arm under load. The cover of the support box, fabricated in two pieces from 1-inch-thick steel plate, is designed to withstand landing-gear loads; seal and protect the support box; limit the full up travel of the support

arm; and serve as a cam surface for the support block cam plate rollers used to guide the pivot motion of the support block. Up and down bumpers are provided to minimize shock from oscillations of the support arm which result when the raised hook cable is trampled by the aircraft wheel.

a. Also contained within the support box is an electrical junction box, sealed with watertight gaskets, which serves the up/down indicating switches and such electrical elements and thermostats required for heater operation

b. A heated drain is provided in the bottom of the support box to avoid the accumulation of water. A screen prevents undesirable items from entering the drainage system. The support-box drain opening is connected to the cross-runway drain which discharges into a heated storage tank that is periodically emptied.

3. HOOK-CABLE TROUGH, G&W PN 52-D-2616: The steel trough provides a protective recess in the runway surface for retraction of the hook cable. It also provides a space for routing the air supply line and heater elements beneath the trough cover on which the retracted hook cable rests. The trough is located 90° to the runway centerline and is aligned with the tape payout side of the BAK-12 arresting-system deck sheaves. Individual trough sections are installed between the support boxes and in a 24-foot series arrangement to each runway edge called the end trough.

4. PNEUMATIC SYSTEM: Compressed air for the pneumatic system is supplied by means of an electric-motor-driven compressor/storage-tank unit (shown in Figure 3 on the following page) This unit is located in the BAK-12 aircraft arrestment energy-absorber pit on the north side of the runway. The air temperature within the pit is maintained at approximately 65° F by means of electric space heaters of the type shown in Figure 4 on the following page. To prevent the accumulation of excessive moisture, the compressed-air storage tank of the unit is periodically blown down and drained. The cut-in/cut-out type pressure regulator of the unit (and system) was adjusted to start and stop the compressor at air pressures of 110 and 125 psi respectively. This type of system was installed instead of the alternate high-pressure air storage bottle system specified in reference (f) because it provides a continuous air supply for the BAK-14 and eliminates the air-bottle handling, charging, and supply problem.

Ref: (f) Research and Development Center, Gulf & Western Industrial Products Company: P-3986, Manual for Operation, Maintenance & Installation of BAK-14 Hook Cable Support System; P-3987, Parts & Drawing Lists

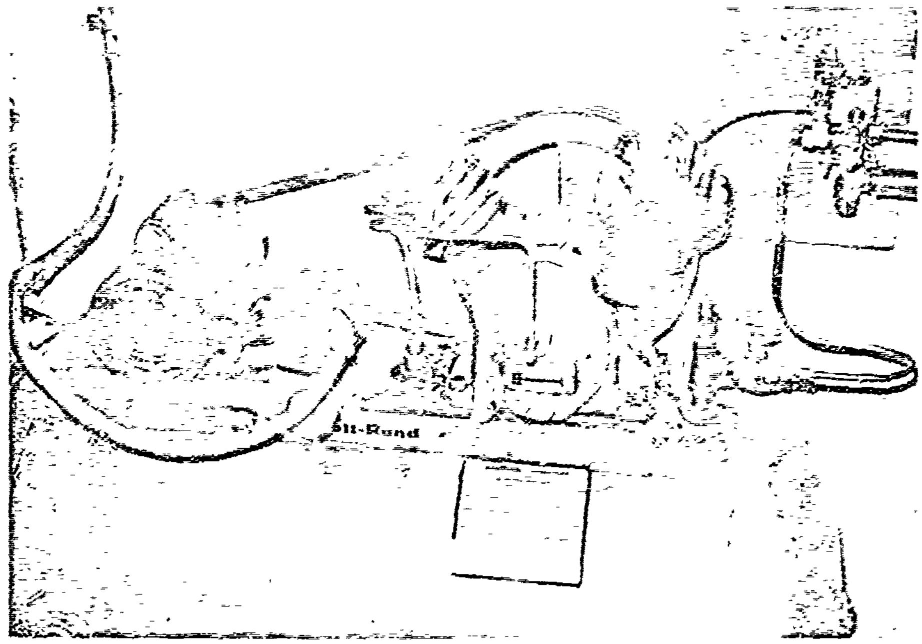


FIGURE 3 - AIR COMPRESSOR/STORAGE-TANK UNIT

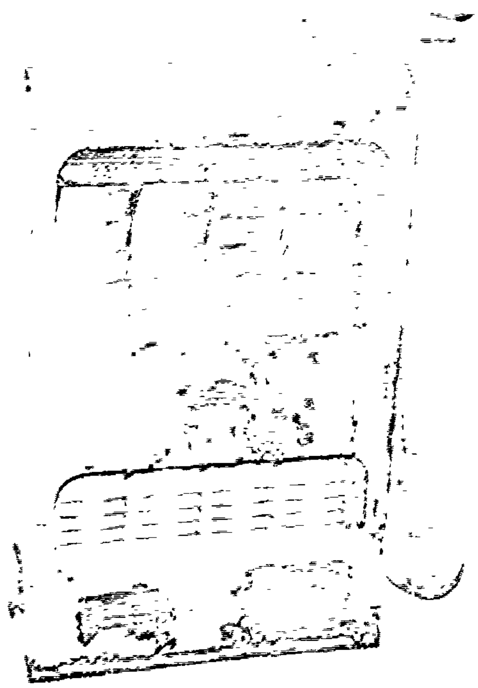


FIGURE 4

ELECTRIC SPACE HEATER

IN BAK-12 PIT

a. The hook cable is lowered when the 3-way solenoid valve (shown in upper right corner of Figure 3, previous page) is energized, allowing compressed air to enter the 5/8-inch-diameter line to the air cylinders in the support boxes. The cylinders apply a force to the off-set yoke of the spring-loaded support arms and lower the hook cable into the trough. The hook cable will remain down as long as the air cylinders are sufficiently pressurized.

b. The hook cable is raised when the 3-way solenoid valve is de-energized or the electric power fails. In either case, the 3-way sole-noid valve shuts off the air supply, and in conjunction with the quick-exhaust valve located in the near-side hand hole at the runway edge, vents the compressed air to the atmosphere. In the event of the loss of either air pressure or electrical power, the torsion springs automatically raise the supports and hook cable; thus the system is fail-safe in the up posi-tion.

c. Manual operation of the system is possible by means of the manual override feature of the 3-way solenoid valve. In the event of an electric power failure, this feature may be used to operate the system.

5. <u>ELECTRICAL CONTROL SYSTEM</u>: The BAK-14 controls operate on 115-volt alternating current, single phase, 60 Hertz power supply. The master control is located in the Galena airfield tower and the portable control at the BAK-12 aircraft arrestment energy-absorber pit on the north side of the runway. Either control may be used to operate the system. The control cables are shielded to prevent malfunctions caused by stray current and interference fields. All control-panel lights have the push-to-test feature.

a. Only the tower master control is provided with a selector switch by which the tower or the portable control may be activated for control of the system. The master control also has a red light to indi-cate the portable control is activated, a switch to raise and lower the hook cable, and lights to indicate the hook cable is up or down.

b. The portable control is installed on the end of a shielded extension cable which is grounded through the disconnect fitting in the BAK-12 pit. These features allow the BAK-14 operator to control (with tower permission) and observe the system operation at the runway edge or to remove the portable control from the system with no effect on tower control. The portable control has a green light to indicate its activation by the tower, a switch to raise and lower the hook cable, and lights to indicate the hook cable is up or down.

c. The raise and retract functions of both controls are monitored by mercury-type limit switches installed on each support arm to indicate whether the arm is up or down. The switches are in series with the system UP/DOWN position indicator light circuit, so failure in any one

support box will prevent the hook-cable position light on the control from lighting. Such failure can be either mechanical or electrical, or a switch malfunction. To avoid checking a multitude of possibilities on the runway, a continuity check circuit (shown in the left side of Figure 5) is provided in the BAK-12 pit which permits locating the faulty switch/ support box. Thus, only one support box need be opened to correct the problem.

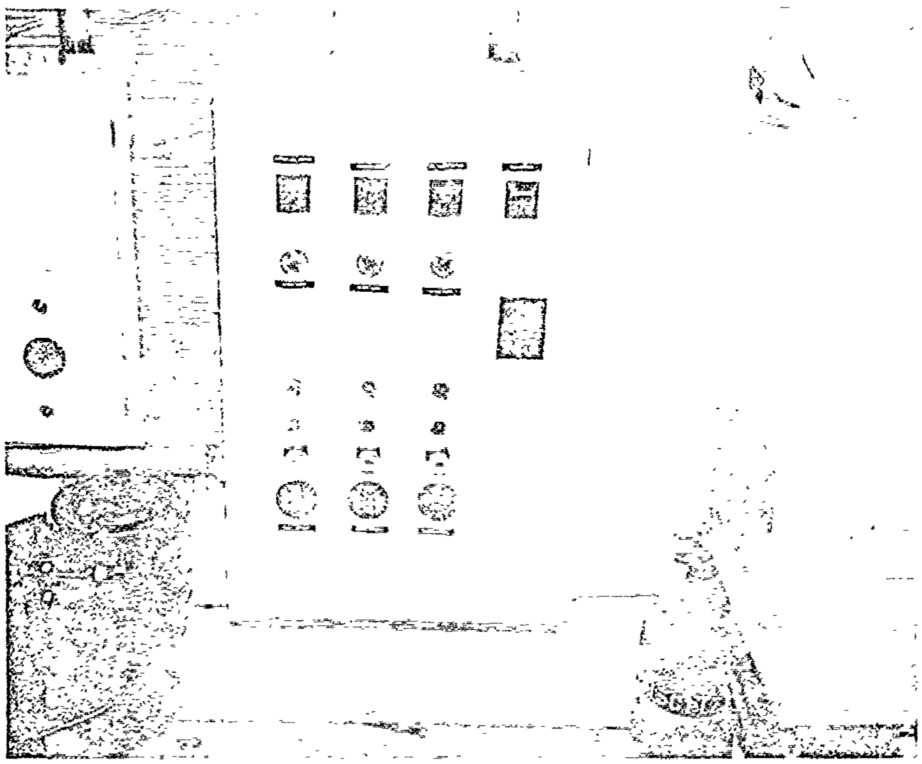


FIGURE 5 - HEATER CONTROL BOX (CENTER) AND THE SUPPORT ARM LIMIT SWITCH CHECK CIRCUIT CONTROL BOX (LEFT)

6. HEATER SYSTEM: The heater system is designed to prevent any moisture trapped in the pneumatic system from freezing and to keep the system free of ice. The runway heaters and their electrical controls are divided into four groups: the support-box heaters, the trough heaters, the end-trough heaters, and the cross-runway drain heaters. All electrical controls for the heaters with the exception of the rate-of-change control (not shown in Figure 5) are located in a wall-mounted control box in the BAK-12 pit shown in Figure 5 above. Power (220-volt alternating current, single phase, 60 Hertz) is supplied to the control box through a manually-operated fused safety switch. Manually-operated ON/OFF thermal circuit breakers limit the power to each heater group. In the case of the cross-runway drain heaters, this is the only control. For the

three remaining heater groups, power is adjusted by means of manual rheostats and regulated by thermostats: a rheostat for each group is located on the panel, and a thermostat for each group is located in the support box, the trough, and the end trough nearest the BAK-12 pit. In addition, each heater group is provided with a rate-of-change control (located above the heater control box) to adapt the heating rate to the seasonal changes in temperature.

a. The heater elements are the mineral-insulated, metallic-sheathed type with potted leads attached to a cold section. The box and trough heaters have a stainless-steel sheath, the drain heaters a copper sheath. All heater units are capable of wet/dry service, and are accessible for replacement.

b. The heater element in the support box surrounds the air cylinder and is in direct contact with the air supply line. The hairpin-shaped trough heater is located on either side of the air supply line in the space below the cover assembly of the trough. One heater is located in each trough section between the support boxes, and two heaters are located in each end trough. The cross-runway drain heaters extend from hand-hole to hand-hole and protect the entire length of the drain.

c. To facilitate detection of heater malfunctions, a continuity check circuit is provided on the heater control box in the BAK-12 pit by which the faulty unit may be identified. The continuity of the drain heaters must be checked at the junction box located in the hand hole on the control-pit side of the runway.

7. <u>BAK-12 AIRCRAFT ARRESTING SYSTEM</u>: A photograph of the BAK-12/BAK-14 installation and the F-4E aircraft is shown in Figure 6 below.

FIGURE 6 - BAK-12/BAK-14 INSTALLATION AND THE F-4E AIRCRAFT

For this test program, the BAK-14 retractable hook-cable support system was used in conjunction with the BAK-12 system which was configured as follows:

a. Type installation - concrete pit, permanent installation with runway-edge sheaves.

b. Location - 2,360 feet from the approach end of runway heading 250°.

c. Arresting-sheave span - as required for a 150-foot-wide runway.

d Hook cable - PN 512875-153, 153-foot-long by 1-1/4-inch-diameter nonrotating wire rope.

8. F-4E AIRCRAFT: Pertinent data is as follows:

a. Configuration - empty fuel tanks installed on the wing pylons.

b. Basic weight - 32,700 pounds.

c. Test weight range - 39,400 to 42,500 pounds.

d. Main-wheel span - 17 feet 11 inches.

III TEST PROCEDURE

A. FUNCTIONAL INSPECTION

1. A functional inspection was initially conducted to determine the condition of the BAK-14 retractable hook-cable support system and to verify its readiness for testing. To expedite the functional inspection, the hook cable of the BAK-12 aircraft arresting system was not installed in the BAK-14 support blocks.

2. Using reference (g) (included as Appendix A of this report) as a working checklist, the BAK-14 heater, pneumatic, and control systems were functionally checked to determine if each control input produced the required response in the system.

Ref: (g) NAVAIRENGCEN Test Directive No. MISC-337 of 8 Nov 1973: BAK-14 Cold Weather Tests at Galena AFB, Alaska

B. DYNAMIC TESTS

1. TRAMPLES AND ARRESTMENTS: After the functional inspection was satisfactorily completed, the hook cable of the BAK-12 aircraft arresting system was installed in the BAK-14 support blocks in preparation for F-4E aircraft tramples and arrestments. The procedures for the dynamic tests were as follows:

a. The hook-cable supports were inspected after each test event. No attempt was made to cycle the system between events.

b. The hook cable was tied to each support block with a doubled length of 550-pound nylon cord for the initial six tramples. To evaluate the hook-cable retention capability of the supports at low ambient temperatures, the nylon restraints were not installed for the remainder of the tests.

c. The tramples and arrestments were conducted on runway heading 250°.

d. The tramples were completed by the touch-and-go method of cycling the aircraft.

e. The taxi-in method of approach to the system was used to complete the arrestments.

f. All arrestments into and high-speed tramples of the BAK-14/BAK-12 were test program events. Another BAK-12 system on the runway was used for operational arrestments.

g. The three-foot-wide runway centerline stripe was used as an OFF-CENTER distance guide during the approaches to the gear; a piece of high-visibility red cloth tied to the hook cable at the desired OFF-CENTER distance was used as the target for the aircraft nosewheel. The desired OFF-CENTER distances (and nominal OFF-CENTER distances of the aircraft), in relation to the aircraft landing gear and the BAK-14 support boxes, are shown in Figure 7 on the following page

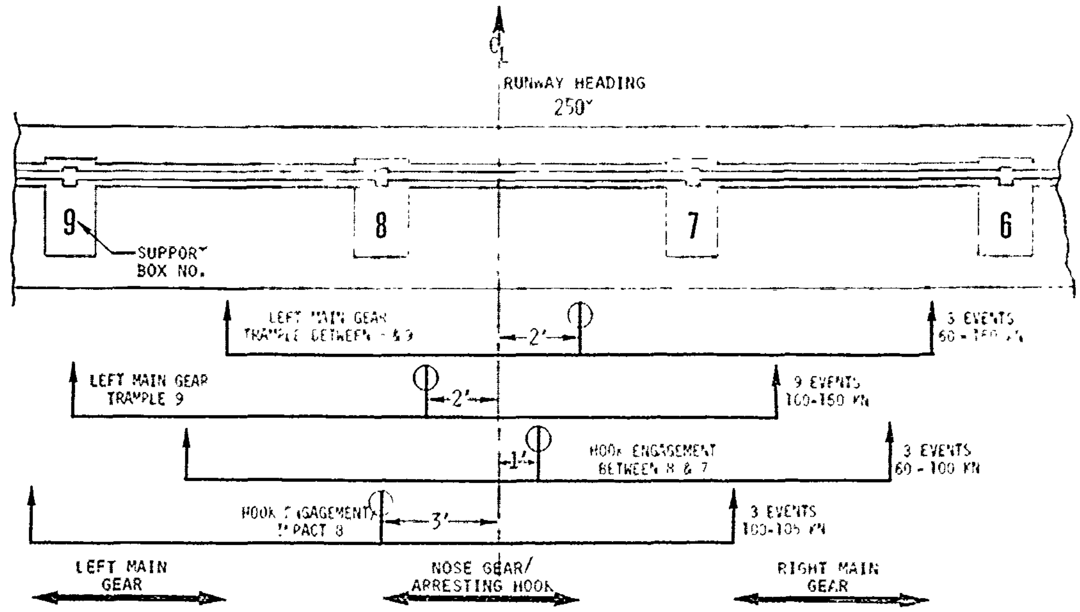


FIGURE 7 - NOMINAL POSITION OF THE F-4E AIRCRAFT LANDING GEAR/ARRESTING HOOK IN RELATION TO THE BAK-14 SUPPORTS

h. Following each arrestment, the hook cable was cleared from the aircraft arresting hook as follows:

(1) System static hydraulic pressure was applied to lock the brakes of the BAK-12 aircraft arrestment energy absorbers.

(2) Aircraft engine power was increased to tension the purchase tapes.

(3) Aircraft engine power was cut to IDLE to cause the tensioned tapes to roll the aircraft aft and clear the hook cable from the arresting hook.

2. <u>100 CYCLE TESTS</u>: These tests were begun after the damage sustained by the BAK-14 during the aircraft testing was repaired. The portable control at the BAK-12 pit and the master control in the runway tower were each used for 50 consecutive cycles.

C. <u>PHOTOGRAPHIC COVERAGE</u>

1. High-speed motion-picture cameras were used to monitor the BAK-14 supports, the hook cable, and the F-4E aircraft during the tramples and arrestments. The coverage was provided by three insulated and electrically heated 16mm cameras, using Kodak 4X7277 black-and-white reversal

film at 200 frames per second. The cameras were located on the south side of the runway and in relation to the hook-cable battery position as follows:

a. A fixed camera located midway between the BAK-12 aircraft arrestment energy absorber pit and the runway-edge sheave directly in line with the hook-cable battery position.

b. A fixed camera and a hand-held pan camera on the edge of the runway located approximately 150 feet upstream of the hook-cable battery position.

2. A winterized 35mm camera was used to take still photographs of the installation, equipment failures, and problem areas.

D. INSTRUMENTATION: The test parameters were visually observed by the Navy test team and measured by direct indicator instruments located in the Galena runway control tower, the F-4E aircraft, and at the BAK-14 test site. The parameters and the methods of measurement are tabulated as follows:

Parameter	Recording Method	Location
Temperature		
Ambient	Thermometer	Galena Tower
Surface	Surface-temperature thermometer	BAK-14 Site
Local ambient	Thermometer	" "
Wind		
Velocity	Anemometer	Galena Tower
Direction	Wind indicator	" "
Aircraft		
Indicated airspeed	Pitot tube instrument	F-4 Aircraft
OFF-CTR position	Direct observation	BAK-14 Site
Gross weight	Basic weight & fuel quantity indicator	F-4 Aircraft
Time	Stopwatch	BAK-14 Site

E. TEST LIMITS: The pilot of the F-4E aircraft determined the flight operating conditions, minimum landing criteria (OPNAVINST 3710.7G (NATOPS General Flight and Operating Instructions Manual)), and safe runway conditions. It was at the discretion of the pilot to brake, arrest, or take off in case of a missed engagement or equipment failure.

IV TEST RESULTS AND DISCUSSION

A. FUNCTIONAL INSPECTION

1. HEATER SYSTEM

a. Surface temperature surveys were taken on the center of the large cover of each support box and the wall of the hook-cable trough (see Figure 8) at one and two feet to the right (north) of each

FIGURE 8 - SURFACE TEMPERATURE THERMOMETER ON TROUGH WALL AND CRACK IN BAK-14 CONCRETE FOUNDATION

support box. The surface temperature of the trough cover assembly could not be obtained because the diameter of the surface thermometer exceeded the width of the trough opening. See Figure 1 for the location and identification of the support boxes in the runway. The conditions during the surface temperature survey were:

Ambient air temperature = -2° F, Chill factor = -3°F
Support-box heater unit power setting = 28%
Trough heater unit power setting = 26%

The results of the survey are presented on the following page.

Support Box No.	Temperature (° F) Box Cover	Trough Wall 1 Ft	2 Ft	Support Box No.	Temperature (° F) Box Cover	Trough Wall 1 Ft	2 Ft
1	-10	5	28	8	-11	17	19
2	-12	17	30	9	- 8	16	19
3	-10	-12	-13	10	-10	12	19
4	- 7	20	24	11	-11	14	19
5	-11	20	35	12	-10	9	18
6	- 9	18	26	13	-10	9	18
7	-10	22	18	14	-12	10	22

(1) When operating at power settings of 28% (above data) or 50% (not recorded), the heaters in the bottom of the support boxes had little or no effect on the surface temperatures of the support-box covers. The maximum heater power setting (100%) produced a surface temperature of only 7° F at a location above the heater element adjacent to the support block.

(2) At a trough heater power setting of 26%, all except one wall temperature were below freezing. These temperatures were lower than expected because the trough remained ice free even though the ambient air temperature was -2° F. It is believed that the temperature of the exposed trough cover assembly remained well above 32° F.

b. The end-trough wall surface temperature was sampled at 7-foot intervals from the outboard support boxes (support boxes 1 and 14) to the end of the trough at the edges of the runway. The results of the survey were as follows:

Trough Heater Power Setting (%)	Temperature (° F) Ambient Air	Chill Factor	End-Trough Wall Temperature (° F) Support Box 1 7 Ft	14 Ft	21 Ft	Support Box 14 7 Ft	14 Ft	21 Ft
50	-16	-45	17	20	22	16	18	20
26	- 2	- 8	46	10	42	40	38	40

The end-trough wall temperatures show a significant difference between the 50% and the 26% heater power settings. The data shows the lower power setting resulted in the higher temperature. It is believed that this anomaly was due to a different rate-of-change control setting which was inadvert ntly used with each heater power setting. However, both sets of temperature data give positive confirmation of heater operation.

c. The temperature at the bottom of each support box was sampled as follows:

Ambient air temperature = -16° F, Chill factor = -45° F
Support box heater power setting = 100%

	SUPPORT BOX NO													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature (°F)	84	88	97	70	68	56	70	54	50	82	44	45	46	84

The 1-foot-long thermometers were placed nearly vertical in each support-box cover opening on the trough side of the raised support block. The variation in the temperatures is due to the differences in the proximity of the thermometer bulb to the heater element in the bottom of the box. The temperature data confirms the operation of the heaters in all of the support boxes.

d. Figure 9 (see next page) shows the results of a fresh snowfall on the BAK-14. The snow remained on the support box covers but melted and/or sublimated directly into the atmosphere in and around the hook-cable trough. The photograph was taken when the ambient air temperature was -16° F and the heater power setting was 50%.

e. All heaters were operative except the trough heater between support boxes 2 and 3. The inoperative trough heater is indicated by the relatively low temperatures on the trough wall adjacent to support box 3 (paragraph a above) and the snow cover on the trough section shown in Figure 9 (next page). The operation of the cross-runway drain heaters was not confirmed.

f. The below-freezing temperature of the support-box covers (paragraph a above) allowed condensate to freeze on the underside of the cover within the support box. This was confirmed later in the testing when the support-box covers were removed. See Figure 10 on the next page.

g. Verification of the electrical continuity of the support-box, trough, and end-trough heaters was attempted by operating the check circuit provided on the heater control panel in the BAK-12 pit. The heater control box is shown in Figure 5 on page 10. The verification was unsatisfactory for the following reasons.

(1) The circuit to the yellow continuity indicator light and/or the red test position indicator light appeared to be incorrectly wired (possibly interchanged) on all three heater circuits.

(2) The relays actuated by the support box and the trough heater operate test switches were exceptionally noisy when placed in the

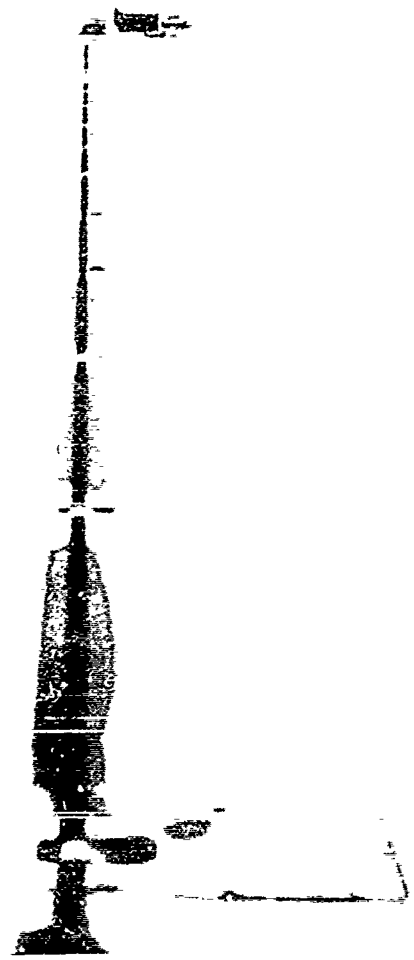
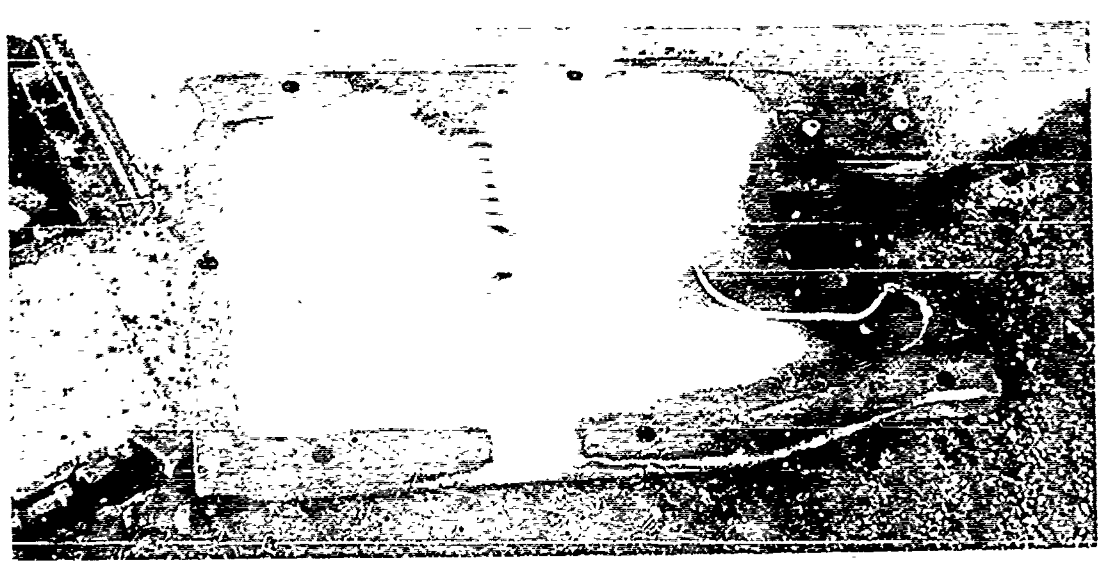


FIGURE 9 - SNOW MELT PATTERN ON THE BAK-14; AMBIENT AIR TEMPERATURE = -16° F, HEATER POWER = 50%

FIGURE 10 - FROZEN CONDENSATE ON INSIDE SURFACE OF SUPPORT - BOX COVER



test position. Although operating personnel attested that the end-trough relay was also occasionally noisy, the relay operated normally during the functional inspection.

(3) The inoperative trough heater between support boxes 2 and 3 was not detected.

h. The control-system and the heater-power-supply voltages were verified to be 112 and 220 volts respectively.

2. COMPRESSED AIR SUPPLY: The compressed air supply source for the pneumatic system is the electric-motor-driven compressor/storage tank unit, shown in Figure 3 on page 8. This unit is installed in the BAK-12 pit on the north side of the runway. The nameplate data is as follows:

Compressor Unit
Ingersoll-Rand Type 30
Model No. 234-1301-1/2TM
Serial No. 30T316515

Air Storage Tank
Wood Industrial Products
N.A.T.V.L.D. 552707
200 psi at 600° F

The cut-in/cut-out type pressure regulator of the unit (and the BAK-14 pneumatic system) supplied compressed air at pressures between 110 and 125 psi. Reference (f) recommends a maximum pressure of 120 psi. The manufacturer's literature included in reference (f) states the air cylinders are designed to operate up to 125 psi.

3. CONTROL SYSTEM

a. The hook-cable supports (with the exception of support 4) and the system position indicator lights on the controls functioned satisfactorily, when activated from either the tower master control or the runway portable control; however, it was necessary to depress support block 4 slightly when it was in the down position in order to energize the system DOWN indicator lights. This might not have been necessary if the hook cable had been installed. The operation and function of the runway/tower selector switch on the tower master control was also satisfactorily demonstrated.

b. The electrical continuity of the support arm UP/DOWN limit switches was verified, using the check circuit provided on the separate control box in the BAK-12 pit. The operation of all the switches, including those on support arm 4, was satisfactory.

c. The time required to raise and to lower the supports (without the hook cable installed) was 13 and 7 seconds respectively.

B. DYNAMIC TESTS

1. AIRCRAFT TRAMPLES AND ARRESTMENTS: These tests consisted of 12 tramples and 6 arrestments of the F-4E aircraft. The purpose of these tests was to determine the effects of landing-gear trample, landing-gear impact, hook engagement, and aircraft-hook impact on the BAK-14 hook-cable supports. The following is a tabulation of the events conducted:

Event		F-4E Aircraft		Speed (Kn)				
No.	Type	Weight (Lb)	Approach	Planned	Indicated Airspeed	Wind (Kn/Dir)	Amb Temp (° F)	Remarks
1	Note 1	42,500	I	60	60	6/310	-24	No damage
2	"	"		80	80	"	"	" "
3	"	NR	Touch/Go	100	150	"	"	" "
4	Note 2	41,500	"	"	"	6/340	"	" "
5	"	41,100	"	"	120	4/340	-23	#7 & 8 restraints failed--not replaced
6	"	41,000	"	"	"	4/330	"	Left main landing gear hit support 9
7	"	41,900	Taxi	"	140	6/340	-16	All restraints removed; nosewheel hit support 8
8	"	41,700	Touch/Go	"	"	4/330	"	
9	"	41,200	"	"	"	3/360	"	
10	"	44,500	Taxi	"	100	8/360	"	
11	"	42,700	Touch/Go	"	145	8/350	"	
12	"	42,400	"	"	"	8/340	"	
13	Note 3	39,400	Taxi	60	60	2/340	"	#7 upstream and #9 downstream slots cracked
14	"	38,700	"	80	80	4/360	"	#8 & 9 latch springs failed; #9 latch shaft bent & anchors detached
15	"	41,700	"	100	100	4/010	-15	#3 & 4 slots chipped; #8 & 14 bases cracked
16	Note 4	40,700	"	"	"	4/330	"	#13 slot chipped; #1-6, 8, & 10-14 bases cracked
17	"	39,700	"	"	105	4/340	"	#3, 5, 6, 8, & 9 bases severely cracked
18	"	"	"	"	100	4/350	"	Hook hit support 8; #5, 6, & 8 detached (5 & 6 remained on cable); #8 slot chipped, latch pivot shaft & anchors detached, pusher block rotated out of alignment

NOTES: The following were attempted:
1. Trample the hook cable with the left main landing gear midway between supports 8 and 9.
2. Trample: Impact support 9 with left main landing gear.
3. Arrestment: Engage hook cable midway between supports 7 and 8.
4. Arrestment: Impact support 8 with the hook.

a. Aircraft Landing-Gear Tramples

(1) The BAK-14 hook-cable support system sustained no apparent damage other than the failure of the nylon cord restraints on supports 7 and 8. The failure of the No. 7 restraint was caused by faulty installation; failure of the No. 8 restraint may have been caused by abrasion of the nylon cord against the support-box cover.

(2) Two probable impacts of the support occurred during the nine attempts as indicated by tire marks on the runway and on the support: support 9 impacted by left main landing gear of the aircraft at 120 knots

indicated airspeed (event 6), and support 8 impacted by nosewheel of the aircraft at 140 knots indicated airspeed (event 7). The BAK-14 hook-cable supports sustained no apparent damage during either of these events. Observation of high-speed motion-picture film of both events revealed that the aircraft tire depressed the support and the support arm into the support box with minimum distortion of the support and the aircraft tire.

b. <u>Aircraft Arrestments</u>

(1) All attempts to engage the BAK-14 supported hock cable were successful; no bolters occurred.

(2) The BAK-14 supports were damaged to some extent during each arrestment because of the detrimental effects of the low temperatures on the supports. Under normal temperatures (above freezing), the rubber supports are pliable. During these tests, however, the extremely low temperatures hardened the supports to such an extent that they fractured during hook-cable pullout. The failures occurred in two areas on the supports: the cable-entry slot and within the metal frame base.

(a) The less serious was the hook-cable entry slot area. Figure 11 shows a damaged support: chunks of rubber were ripped out, enlarging the cable entry slot. Supports 7 and 9 were damaged in this manner during the initial engagement (event 13) at 60 knots indicated airspeed. A high-speed motion-picture film sequence of this event is shown in Figure 12 on the following page.

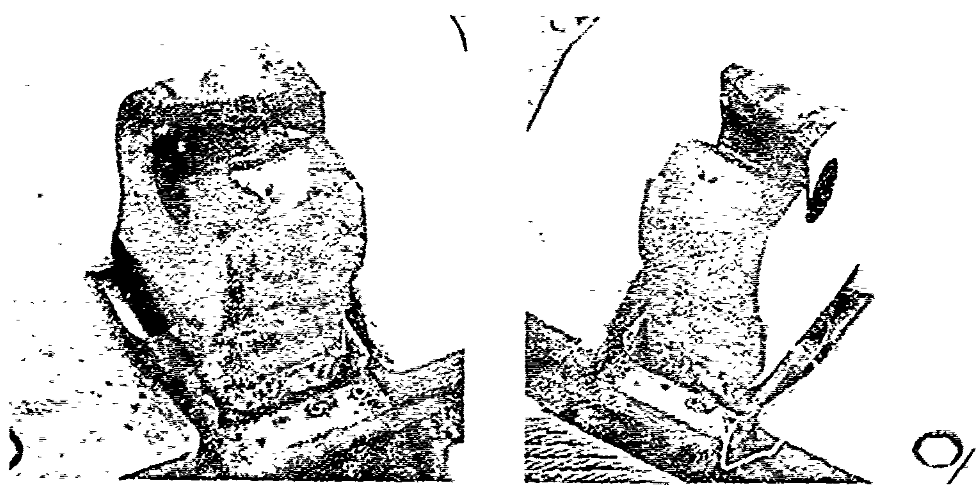


FIGURE 11 - FAILURE OF SUPPORT AT THE HOOK-CABLE ENTRY-SLOT AREA

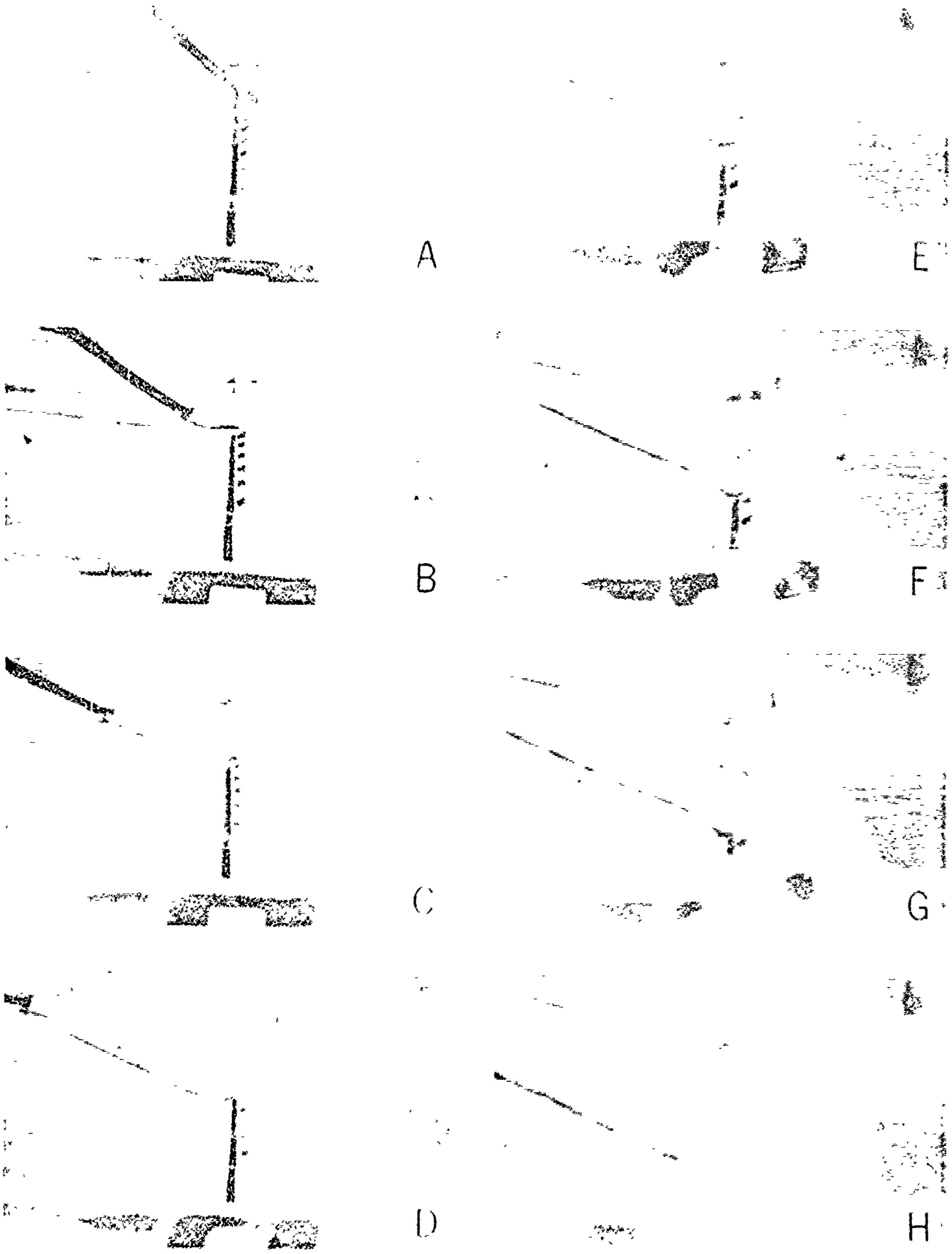
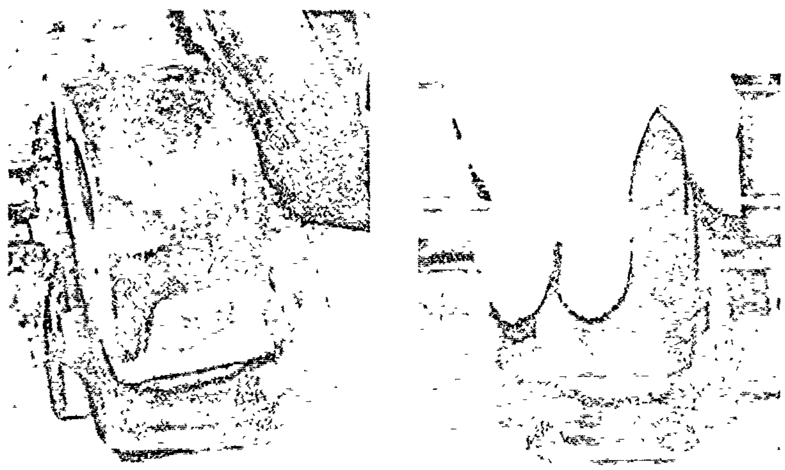
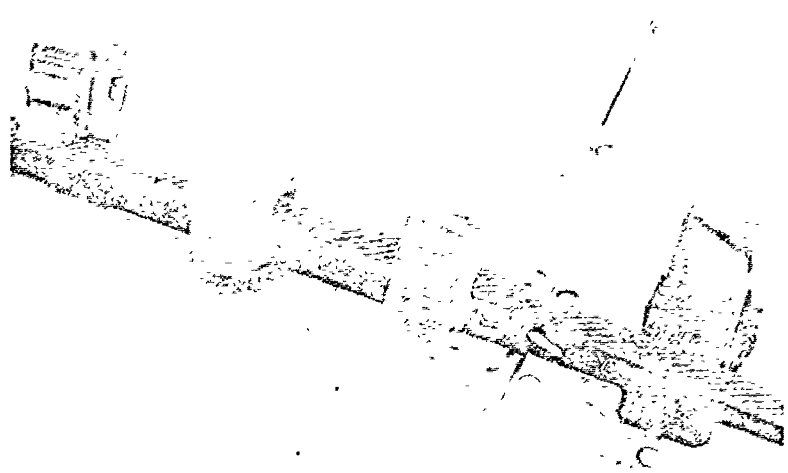


FIGURE 12 - HIGH-SPEED MOTION-PICTURE FILM SEQUENCE OF EVENT 13: F-4E AIRCRAFT 60-KNOT INDICATED AIRSPEED ENGAGEMENT OF BAK-12 ARRESTING SYSTEM EQUIPPED WITH BAK-14 HOOK-CABLE SUPPORT SYSTEM

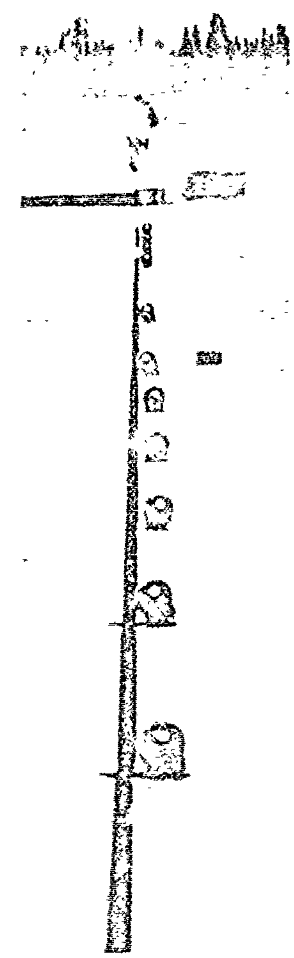
(b) The more serious area of failure occurred within the metal frame base of the support as shown in Figure 13, where the rubber partially separated from the base. After the last arrestment, supports 5, 6, and 8 were separated from their bases, and supports 5 and 6 remained attached to the hook cable during the arrestment and retrieve (see Figure 13). All the remaining supports were split and partially separated from their bases (see Figure 13). The failure mode indicates that both the nylon-restraint and the pivot-shaft through holes decrease the area of the load carrying cross section and seriously weaken the support within the metal frame base.



PARTIAL SEPARATION FROM BASE



SUPPORTS 5, 6, & 8 SEPARATED FROM BASES, EVENT 18



SUPPORTS AFTER FINAL ENGAGEMENT EVENT 18

FIGURE 13 - VIEWS OF FAILED CABLE SUPPORTS

(3) During event 14, the pivot shaft brackets, G&W PN 52-B-7022-1, in support boxes 8 and 9 were dislodged from their position on the support arm when the 10-32 x 3/8-inch-long self-tapping attachment screws, G&W PN 52-E-768-36, backed out. As a result, the freed 1/2-inch-diameter x 5-inch-long latch pivot shaft, G&W PN 52-B-7023-1, in support box 9 apparently dropped below the support arm, struck and dented the wall of the air cylinder, G&W PN 52-E-768-15, and was bent at an oblique angle by the arm when the cable was trampled by the aircraft (see Figure 14). During event 18, the pusher block, G&W PN 52-B-6198-1, on the end of the air cylinder piston rod in support box 8 was rotated out of alignment with the forks of the offset yoke on the support arm.

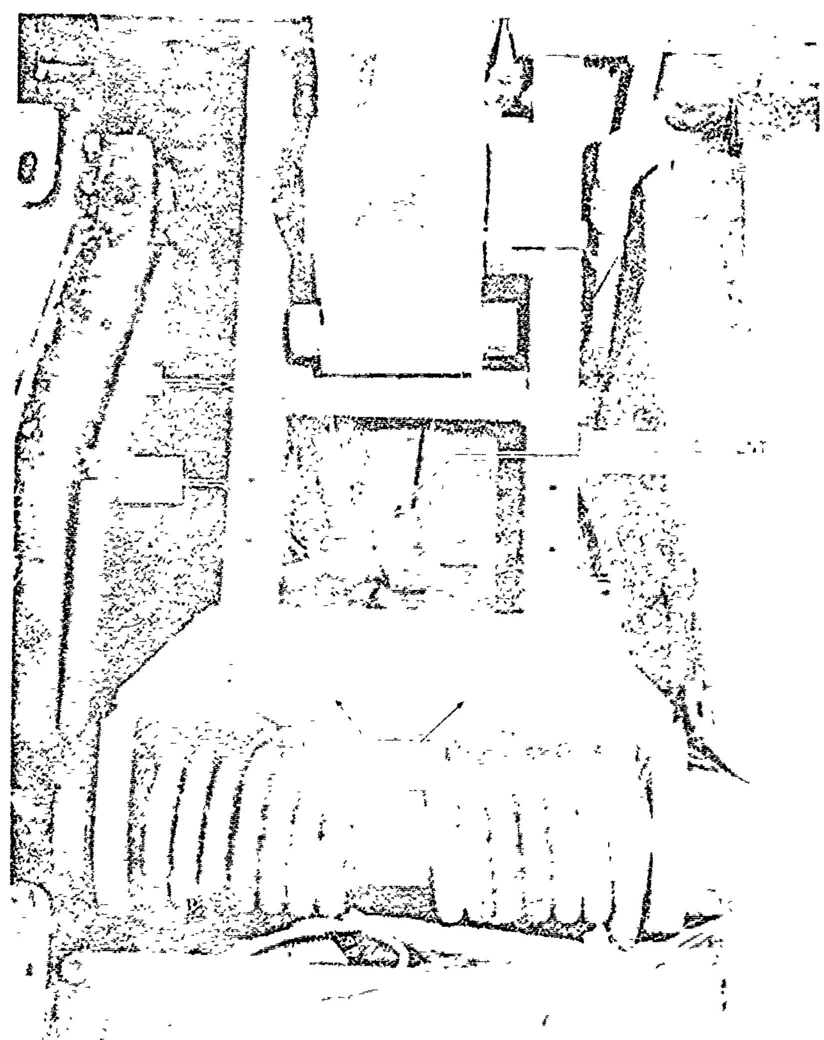


FIGURE 14 - BENT PIVOT SHAFT AND LOOSE PIVOT-SHAFT BRACKETS OF SUPPORT BOX 9

(4) The latch extension springs, G&W PN 52-C-3247-3, in support boxes 8 and 9 were also dislodged from their attachment pins during event 14. During reinstallation, it is necessary to excessively distort the loop end of the springs because of the poor accessibility of the attachment pins.

(5) Nosewheel tire marks on the runway following the last arrestment (event 18) indicated a probable aircraft-arresting-hook impact of support 8 at an indicated airspeed of 100 knots. The validity of the event for hook-impact evaluation is questionable because the support was partially separated from its base as a result of the previous events. In view of the damage incurred during normal arrestments, it would appear that the support would be severely damaged by a direct hook impact.

2. CYCLE TESTS: After the aircraft tests were completed, the BAK-14 was returned to operating condition for the 100 cycle tests as follows: the 14 damaged supports were replaced; support box 8 pusher block was realigned; the bent latch pivot shaft of support box 9 was straightened; the pivot shafts of support boxes 8 and 9 were reinstalled with their brackets fastened to the support arm with 10-32 x 1/2-inch-long screws; and 5 support-block latches were adjusted. After the repairs were completed, system cycle operation was satisfactory; however, when the initial 50-cycle test was started, the latch of support block 4 would not retract and prevented retraction of the entire cable (retract hangup) as shown in Figure 15. Adjustment of the latch corrected the problem.

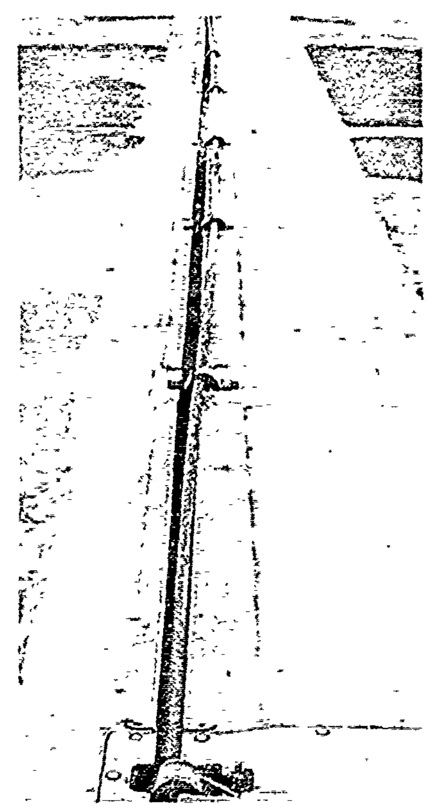


FIGURE 15 - HOOK-CABLE RETRACT HANGUP CAUSED BY JAMMED SUPPORT LATCH

a. At ambient temperatures ranging from -33° F to -36° F, the BAK-14 supported hook cable was cycled 50 times in succession using the portable control and then 50 times using the tower master control. Prior to the second series of 50 cycles, a latch mechanism (on support block 3) again had to be adjusted in order to obtain full operation of the system. During initial operation, the air supply pressure (regulated range of 110 to 125 psi) maintained by the compressor unit was sufficient to produce full travel of the supported hook cable. When the pressure decreased to

approximately 70 psi due to the high air consumption of the continuous cycling, the hook cable would not fully retract. The compressor was then allowed to recharge the storage tank. The cycling was resumed in sets of 10 cycles, with a pause between each set to allow the compressor to recharge the air storage tank.

b. The average time required to raise and lower the hook cable with either control was approximately 13 and 7 seconds respectively. This compares to the 15- and 8-second raise and lower cycle times of the reference (e) system prior to the installation of a quick-exhaust valve, Schrader PN 30077-9500, in the air supply line at the three-way solenoid valve and in the hand hole at the runway edge. With these valves installed, the time required to raise the reference (e) system was decreased to 5 seconds, which resulted in 13 seconds for the combined raise/lower cycle. The Air Force requirement is a maximum time of 15 seconds. The preload of the support-arm torsion springs may also affect system cycle time. The torsion springs of the subject system are preloaded with 1.484-inch-diameter spring blocks, G&W PN 52-B-6170-2. The reference (e) torsion springs provide a greater preload because of the 2.25-inch-diameter spring blocks in each outboard box and the 1.625-inch-diameter spring blocks in the remaining boxes.

c. The hook cable DOWN indicator light on both the portable and the tower controls did not function during the cycle tests. The cause of the malfunction is not known. It could be the result of damage caused by the aircraft tests or the incorrect reinstallation of the mercury switches following support-box repairs, since adequate instructions concerning installation of the switches were not available.

d. The hook-cable trough remained ice free during the entire test cycle at temperatures ranging from -33° F to -36° F.

C. TEST EQUIPMENT

1. HOOK-CABLE INSTALLATION

a. At an ambient temperature of -24° F, it took five men, two using a 1-inch-diameter pipe and a pry bar, 1/2 hour to install the hook cable in the retention hole of the BAK-14 supports. The neoprene rubber supports were extremely hard and stiff. Maximum manual effort was required to open up and align the diagonal entry slot in the support top so the hook cable could be forced in.

b. To facilitate installation of the hook cable in the supports, the installation tool shown in Figure 16 on the following page was fabricated. Hook-cable installation time was reduced to less than 10 minutes using 4 or 5 men: 2 men used the tool to open the entry slot, 2 men used pry bars (1 to align the opened slot with the hook cable and one to prevent movement of the support arm), and 1 man to insert the cable.

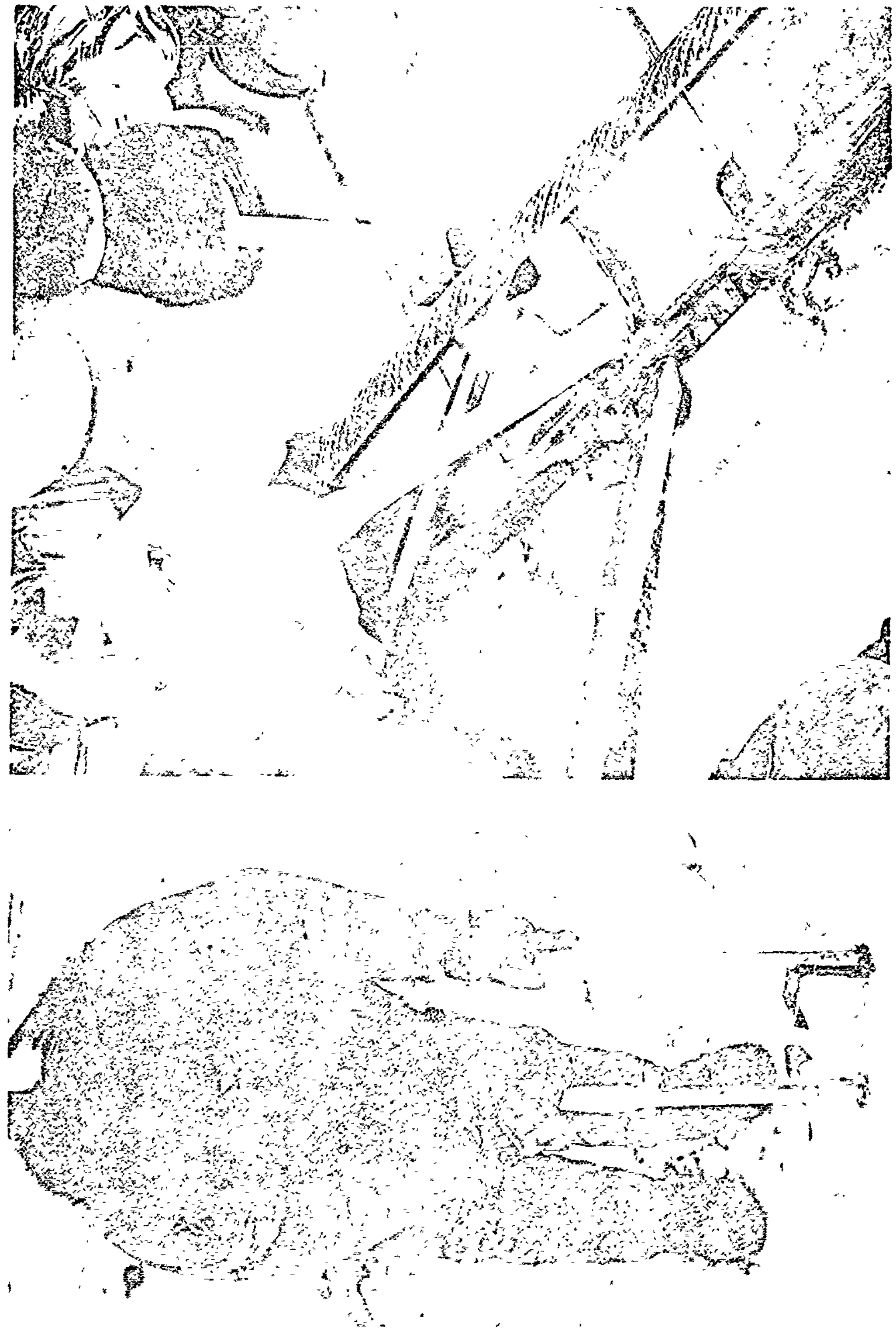


FIGURE 16 - HOOK-CABLE INSTALLATION TOOL AND HOOK-CABLE INSTALLATION

It is believed that the addition of a crosspiece on each handle of the installation tool would allow it to be used to both open and twist the entry slot of the support to align it with the hook cable, thereby eliminating the need for one of the pry bars.

2. HOOK-CABLE RESTRAINT INSTALLATION

a. Nylon cord restraints were installed on each BAK-14 support as shown in the example in Figure 17. Installation of the restraints on the supports at the test site was easily accomplished because of the

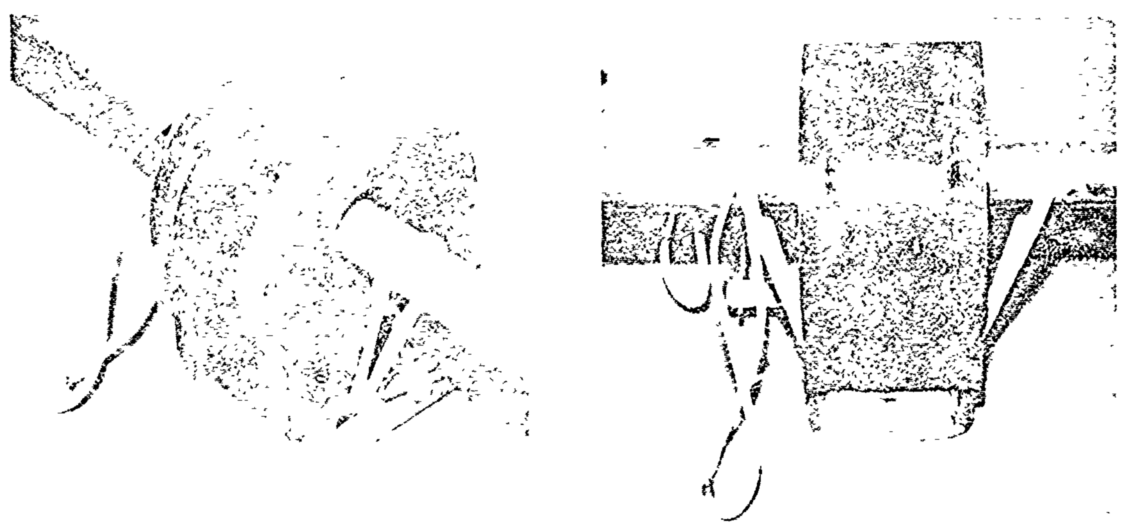


FIGURE 17 - EXAMPLE OF NYLON CORD RESTRAINT INSTALLATION

through hole in the metal frame base of the support block. The through hole is aligned with the relieved area of the cover as shown in Figure 18 on the following page. It was a simple task to place a loop of nylon cord (ends fused) over the hook cable on one side of the support, pull the loop ends through the hole to the opposite side of the support with a piece of heavy safety wire, and then tie the loop ends around the hook cable.

b. It was originally planned to use the nylon restraints on the BAK-14 supports for all the aircraft tests. After experiencing the excessive effort necessary to install the hook cable in the supports, however, it was decided to remove the nylon restraints after the initial six test events. During the remaining events, the hook-cable-retention capability of the supports (without restraints) at low temperature conditions was evaluated. Visual observation indicated that the hook cable was retained by the supports during the landing-gear-trample portion of the remaining 12 events; however, it appears advisable to install nylon restraints on those supports damaged in the hook-cable-retention area.

FIGURE 18 - SUPPORT BASE THROUGH HOLE AND RELIEVED AREA IN COVER PROVIDED FOR INSTALLATION OF NYLON RESTRAINT

3. SUPPORT REPLACEMENT

a. All 14 damaged supports were replaced under -16° F ambient temperature conditions at the conclusion of the aircraft tests. The replacement of each support involved the handling and manipulation of the following components: (1) large cover of support box, G&W PN 52-D-2610-1 (seven 1/2-inch-diameter bolts); (2) support shaft, G&W PN 52-B-6442-1 (two lock pins); (3) two support springs, G&W PN 52-D-3247-3; and (4) support cam block, G&W PN 52-B-7026 (two Allen screws).

b. With varying degrees of difficulty and discomfort, most of the manipulation of items (1), (2), and (4) was accomplished while wearing the protective leather gloves with the woolen glove inserts shown in Figure 19 on the following page. Maximum protection from the temperature, which is afforded by the simultaneous use of the inserts, gloves, and mittens shown in Figure 20 on the following page, is obtained at the sacrifice of all manipulative ability. The use of bare hands was required for access to and manipulation of item 3 as shown in Figure 21 on page 32. The extreme discomfort and possible risk of frostbite injury was moderated to some extent by the heater in the open support box.

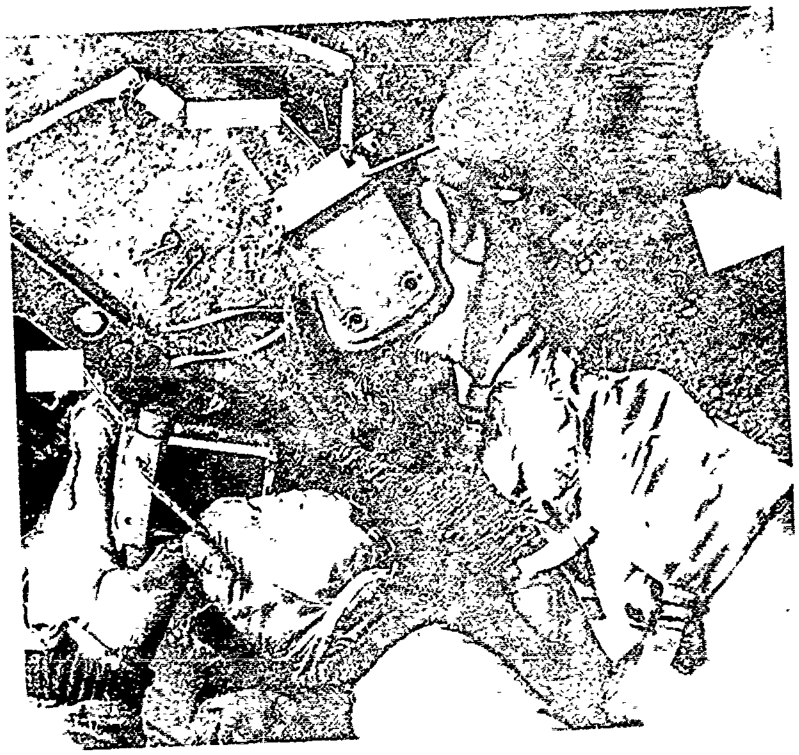


FIGURE 19

CAM BLOCK INSTALLATION AND TOE PLATE REMOVAL FROM SUPPORT

FIGURE 20

COLD-WEATHER HAND PROTECTION WORN BY AIR FORCE MAINTENANCE PERSONNEL

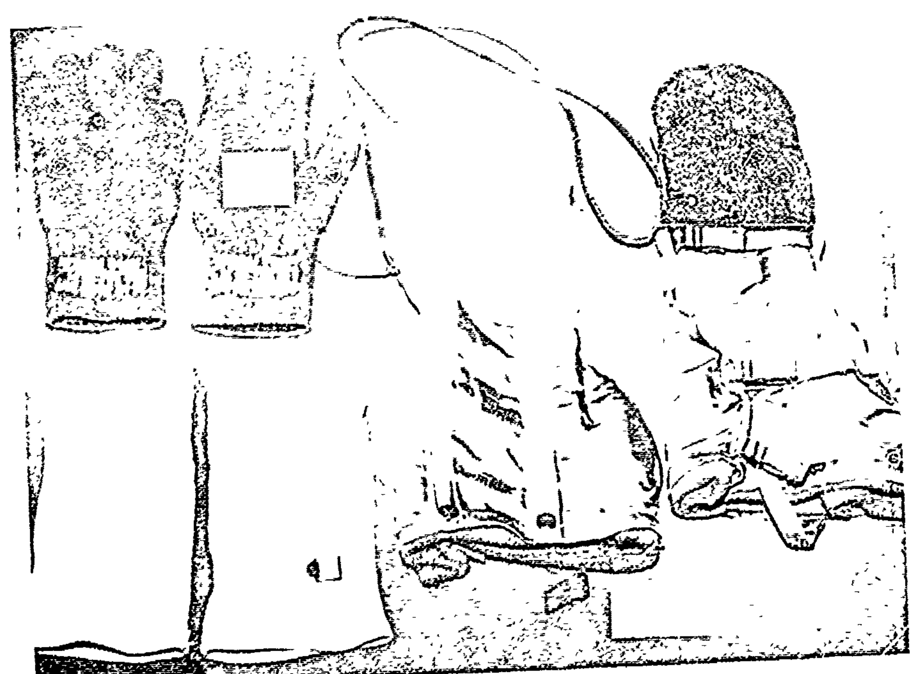


FIGURE 21 - REMOVAL OF SUPPORT-BLOCK EXTENSION SPRINGS WITH BARE HANDS

4. LATCH-SPRING REPLACEMENT: Because of the inaccessibility of the spring attachment roll pins, the half loops on the ends of the spring were distorted to facilitate installation around the roll pins. It was necessary to remove the protective gloves in order to manipulate the spring and the installation tool (needle-nose pliers). Removal of the roll pins as an alternate means of installation was not attempted. The method used by the contractor for the initial installation of the springs is not known.

5. SUPPORT-BLOCK LATCH ADJUSTMENT: The large cover plate and its seven 1/2-inch-diameter bolts must be removed from the support box in order to gain access to the support-block latch adjustment. The adjustment device consists of a bolt/dual jam nut arrangement by which the wire-rope assembly, G&W PN 52-B-7024-1, is shortened or lengthened. To make this adjustment, maintenance personnel must remove their gloves. The length of the wire rope is critical for proper latch operation: if the wire rope is too long, the latch will jam; if too short, the latch will not lock. Tension is retained in the wire-rope assembly when the support arm is actuated by the air cylinder. The support arm, however, is designed to move (swing) independently of the air cylinder when the hook cable is trampled by the aircraft or the support is impacted by the aircraft tire. When this occurs, the tension is released from the wire-rope assembly when the arm goes down and then is suddenly recovered when the arm returns to

the up position. It is possible that repetitive tension recovery is sufficient to cause the wire-rope assembly to stretch and/or pull through the retaining plate, G&W PN 52-B-7018. Seven latch adjustments were required during the tests: five during replacement of the supports after the aircraft tests; and one prior to each 50-cycle test.

6. MACADAM MATERIAL: The trough and the inside of the support boxes were heavily coated with macadam material loosened from the runway surface. It was a nuisance that hindered inspection because the macadam covered all exposed parts. Sufficient accumulation could jam the latches or clog the drain opening in the support box.

7. CONCRETE FOUNDATIONS: Figure 8 on page 16 shows lateral cracks in the concrete foundation of the BAK-14. These cracks were visually observed prior to conducting the tests. It is highly probable that additional cracks may result from further settling of the foundation.

8. AIRCRAFT: The F-4E aircraft was not damaged during the testing. A routine nosewheel tire change was necessary after the sixth test event because of excessive tread wear.

V RELIABILITY

A. Although the confidence level is low because of the small size of the data sample, reliability was calculated to mathematically describe the operational suitability of the BAK-14 retractable hook-cable support system in natural low-temperature conditions. Reliability was based on actual failures which occurred during tests. The reliability function of the geometric probability distribution as recommended in reference (h) was used. The formula is:

$$Rg\ (k) = \left(1 - \frac{1}{h}\right)^k$$

where Rg (k) = The reliability at (k) cycles of any test sequence

and (h) = The estimated mean number of cycles between failures

B. When the estimated mean number of cycles between failures of the support latch mechanism is 51, the cyclic (raise/lower) reliability of the BAK-14 system is $(.980)^k$ as follows (see next page):

Ref: (h) NAVAIRTESTFAC Report No. NATF-COS-3 of 22 Dec 1972: Analytical Techniques for Cyclical Equipment Exhibiting Reliability Growth

k (Cycles)	Rg (k) (Reliability)
10	.817
20	.668
30	.546
40	.446
50	.364

C. When the estimated mean number of cycles (arrestments) between complete failure of one or more supports is seven, the reliability of achieving full battery position of the hook cable is $(.857)^k$ as follows:

k (Cycles)	Rg (k) (Reliability)
2	.734
4	.539
6	.396
8	.291
10	.214

VI CONCLUSIONS

A. The BAK-14 retractable hook-cable support system is not suitable for use in low-ambient temperature conditions because of the structural failure of the cold-hardened neoprene rubber of the support block, and the related failure and high maintenance requirement of the support-block latch actuating mechanism during aircraft engagements. (Section IV, paragraphs B1b and C5)

B. CYCLIC PERFORMANCE

1. The cyclic ability of the BAK-14 system was unsatisfactory. (Section IV, Paragraph B2a)

2. The load of the tensioned hook cable had no effect on the system cycle time (raise 13 seconds, lower 7 seconds) because cycle times with and without the hook cable installed were the same. (Section IV, Paragraphs A3c and B2b)

3. The 20-second cycle (raise/lower) time of the system exceeds the Air Force maximum time requirement by five seconds. (Section IV, Paragraph B2b)

C. Functional checkout of the BAK-14 control system was satisfactory. (Section IV, Paragraph A3)

D. HEATER SYSTEM

1. The temperature survey confirmed that all support-box and trough heaters were operating except the defective trough heater between support boxes 2 and 3. (Section IV, Paragraph A1)

2. Operation of the cross-runway drain heaters was not confirmed. (Section IV, Paragraph A1e)

3. Visual observation during the test period indicated the trough heaters maintained the system free of ice at -36° F ambient temperature conditions. (Section IV, Paragraph B2d)

4. The formation of moisture (frozen condensate) on the underside of the support-box covers may contribute to the corrosion of components within the support box. (Section IV, Paragraph A1f)

5. The heater continuity check circuit operate/test switches are incorrectly wired. (Section IV, Paragraph A1g)

6. The relays activated by each heater continuity check circuit operate/test switch are defective in the test position. (Section IV, Paragraph A1g)

E. The BAK-14 was not damaged when trampled by the aircraft landing gear. (Section IV, Paragraph B1a)

F. SUPPORT BLOCKS

1. The support blocks were not damaged when the hook cable was trampled by the aircraft main gear. (Section IV, Paragraph B1a)

2. The neoprene rubber support blocks were unsatisfactory because of their hardened condition at the low ambient temperatures. The loads imposed during arrestments caused partial to complete separation of the 14 blocks from their bases. (Section IV, Paragraph B1b)

3. Although a previously damaged support separated from its base as a result of arresting-hook impact, the arrestment was successful. (Section IV, Paragraph C1)

4. Installation of the hook cable in the retention hole of the support block was difficult and time consuming, due to the hardened condition of the neoprene rubber at the low ambient temperatures. (Section IV, Paragraph C1)

5. The nylon-restraint and pivot-shaft through holes seriously weaken the base of the support. (Section IV, Paragraph B1b)

G. HOOK-CABLE RESTRAINTS

1. The nylon restraints are subject to failure. (Section IV, Paragraph B1a)

2. Installation of the nylon cord restraints was easily accomplished. (Section IV, Paragraph C2)

3. Although nylon cord restraints are not required at low ambient temperatures because of the increased hook-cable retention capability of the supports, they should be installed on those supports that are damaged in the hook-cable entry slot area. (Section IV, Paragraph C2)

H. SUPPORT-BOX ASSEMBLY

1. The self-tapping attachment screws, G&E PN 52-E-768-36, of the pivot shaft brackets are unsatisfactory. (Section IV, Paragraph B1b(3))

2. The alignment of the pusher block with the forks of the support arm offset yoke was not maintained during the engagements. (Section IV, Paragraph B1b(3))

3. The latch extension springs, G&W PN 52-C-3247-3, dislodged during the engagements and are unsatisfactory. (Section IV, Paragraph B1b(4))

4. At certain stages of support replacement, latch spring replacement, and latch adjustment, maintenance personnel must remove all hand coverings in order to handle parts at very low ambient temperatures. (Section IV, Paragraphs C3, C4, and C5)

5. Latch mechanism adjustments (1 per each 50 cycles) are necessary because the wire-rope stretches and/or slips in the retaining plate. (Section IV, Paragraph C5)

6. Latch mechanism adjustments are time consuming because the large cover plate must be removed from the support box. (Section IV, Paragraph C5)

7. The support-arm mercury switches were either defective or incorrectly reinstalled following aircraft tests. (Section IV, Paragraph B2c)

I. Cracks have developed in the concrete foundation of the BAK-14. (Section IV, Figure 8 and Paragraph C7)

J. The F-4E aircraft was not damaged during the tests. (Section IV, Paragraph C8)

VII RECOMMENDATIONS

A. SYSTEM CYCLE TIME: To improve system cycle time, install a quick-exhaust valve in the air supply line at the three-way solenoid valve location.

B. HEATER SYSTEM

1. Replace the inoperative trough heater and the improperly wired lights of the heater check circuit.

2. Replace the noisy heater test relays with relays of an improved design.

3. Confirm the operation of the cross-runway drain heater.

C. SUPPORT BLOCK: As possible means to decrease the support failures caused by engagements at low ambient temperatures, the following are suggested:

1. INTERIM CORRECTION: Remove the upper portion of the hook-cable retention area of the supports. Test the modified supports in conjunction with nylon restraints at moderate ambient temperatures (50° F to 80° F).

2. PERMANENT CORRECTION

a. Redesign and fabricate a support block with a suitable material that will maintain the necessary strength and toughness over the expected operating temperature range of the BAK-14 system.

b. Increase the load-carrying cross section within the metal frame base of the support by eliminating the two through holes and by providing other means for anchoring the nylon restraint and pivoting the support.

D. SUPPORT-BOX ASSEMBLY

1. Coat all metal surfaces within the support box that are subject to corrosion with corrosion-resistant paint, compound, or lubricant, whichever is applicable.

2. Replace the self-tapping attachment screws, which anchor the pivot shaft brackets to the support arm, with through bolts.

3. Furnish the pusher block with a positive guide to maintain its rotational alignment with the forks of the support-arm offset yoke.

4. Due to the severe cold conditions in the region of intended use, redesign the support-box assembly with maintenance-free operation as the primary objective. Failing this, make possible problem areas of the design accessible so that gloves may be worn by maintenance personnel.

5. Redesign the latch extension springs to provide increased reliability.

6. To improve the performance of the latch-actuating mechanism, the following are suggested:

a. Interim Correction

(1) Improve the retaining plate anchor of the wire-rope assembly and install a device to eliminate shock loading in the wire rope.

(2) Provide an access hole in the large cover of the support box to allow adjustment of the wire rope without removing the cover.

b. Permanent Correction: Redesign the latch-actuating mechanism to eliminate the wire-rope assembly.

E. Thoroughly examine BAK-14 concrete foundations for defects.

VIII REFERENCES

(a) NAVAIRSYSCOM msg 022118Z Jan 1974: Cold Weather Testing of BAK-14 Galena Alaska

(b) NAVAIRTESTFAC Report No NATF-EI-108 of 31 Aug 1964: Evaluation of Retractable Pendant Supports for the Federal Aviation Agency

(c) Air Force Systems Command, Aeronautical Systems Division, Technical Report No ASD-TR-69-9 of Aug 1969: BAK-14/F32 Retractable Cable Support System

(d) Air Force Systems Command, Air Force Flight Test Center, Technical Report No. FTC-TR-72-41 of Mar 1973: Testing of the BAK-14 Retractable Cable Support System

(e) NAVAIRTESTFAC Report No. NATF-EN-1128 of 22 Jan 1974: Evaluation of the BAK-14 Retractable Hook-Cable Support System

(f) Research and Development Center, Gulf & Western Industrial Products Company: P-3986, Manual for Operation, Maintenance & Installation of BAK-14 Hook Cable Support System; P-3987, Parts & Drawing Lists

(g) NAVAIRENGCEN Test Directive No. MTSC-337 of 8 Nov 1973: BAK-14 Cold Weather Tests at Galena AFB, Alaska

(h) NAVAIRTESTFAC Report No NATF-CCS-3 of 22 Dec 1972: Analytical Techniques for Cyclical Equipment Exhibiting Reliability Growth

APPENDIX A - NAVAIRENGCEN TEST DIRECTIVE

TEST DIRECTIVE

4ND-NAEC-2030(REV 3-72) TD NO. MISC-337

FROM: DIVISION SUPERINTENDENT (NE-7) ENGINEERING DEPT. NAEC (SI)	PROBLEM ASSIGNMENT J.O. 497013 EFFORT NORMAL	DATE 8 Nov 1973 SHEET 1 OF 4
TO: NATF AFSC	SUBJECT BAK-14 Cold-Weather Tests at Galena AFB, Alaska	
	PROJ. ENGR MR. C. RIVERS NE-713	REV / DATE / INIT
	DEV ENG. MR. C. SAMBUCHINO NE-732	
	AUTHORIZATION EO 73-632	

REF: (a) BAK-14 Hook Cable Support System Operation, Maintenance and Installation Manual: Gulf and Western No. 3986
(b) BAK-14 Hook Cable Support System Parts and Drawings Manual: Gulf and Western No. P-3987
(c) NATF message 211956Z Sep 1973

PURPOSE: To functionally and dynamically test the BAK-14 Retractable Cable Support System in a cold weather environment with United States Air Force Aircraft.

EQUIPMENT

1. BAK-14 Retractable Cable Support System, with heaters, installed in accordance with Department of the Air Force (Gulf and Western) drawings No. 52-E-770 and 52-E-900.

2. BAK-12 Aircraft Recovery System for a 150 ft runway.

3. Three 1-1/4" x 153 ft deck pendants, PN 512875-153.

4. F-4E aircraft.

5. Weather monitoring device for wind velocity and ambient temperature.

6. Communications link between the test team and the aircraft pilot.

7. One 1" x approximately 1-1/2 ft long pipe.

8. One stop watch.

9. Contact surface pyrometer.

NUMBER OF INFORMATION COPIES TO

NE-39		NI-2	2
NE-632		NI-4	1
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NE-713(PM)	1	AFSC	4
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NE-72	1	NATF	IR
		NATF	X

Issued 11/13/73

ENCLOSURE (1) TO NAEC LTR
SERIAL ______ DATE ______

PREPARED
/s/ RALPH M. ZECCA NE-732

APPROVED
/s/ H. J. RAMBO
BY DIRECTION

PLATE NO. 15306

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TEST PROCEDURE

Phase I: A prefunctional inspection is to be performed to insure that the system is ready to be tested. The following items are to be checked:

1. Record the "Support Box", "Trough" and "End Trough" heater power settings.

2. Record the surface temperature at each support box, and at points one and two feet from each support box along the trough.

3. Record the temperature in the trough at seven-foot intervals between the last support box and the end of the trough.

4. Check that the inlet and delivery pressures of the regulator, G&W PN 52-C-3861, read 3000 PSIG and approximately 100 PSIG. The delivery pressure should read between the red lines on the pressure gage.

Phase II: A functional test is to be performed to determine that the system is operationally sound for aircraft tests. References (a) and (b) will be used for operating instructions. The following tests will be required:

1. Press to test all lights on the Tower, Runway and heater control boxes to insure that the lights illuminate. Replace faulty bulbs.

2. Heater continuity, circuit check

(a) Turn on the heater support box test switch and the heater support box circuit breaker. The support box heater test light should illuminate. An unlit light indicates an inoperative heater. Since the heaters were checked during Phase I when the temperature readings were taken, an unlit light indicates a faulty circuit.

(b) Rotate the support heater continuity selector through all the support box positions. Check the test light at each position.

(c) Return the heater support box test switch to the "off" position.

NOTE: When the heater support box, trough, and end trough test switches are turned on, no heat is being provided. Therefore, these tests must be conducted as rapidly as possible, and the test switches returned to the "OFF" position.

(d) Repeat the above test for the trough and end trough heaters using their appropriate test switches.

3. Limit Switch Continuity Check

(a) Place the Tower/Runway switch located on the tower control box in the "Runway" position.

(b) Place the Up/Down switch on the runway edge control box in the "UP" position. The "UP" light should illuminate.

(c) Rotate the limit switch continuity test selector, located on the malfunction locator box in the tower, through all the positions. Check the "UP" light each time. An illuminated light indicates that the limit switch is properly closed.

(d) Repeat the test with the Up/Down switch in the "Down" position.

4. Tower/Runway Control Tests

(a) Place the Tower/Runway switch in the "Tower" position.

(b) Activate the BAK-14 System. Record the time required to raise and lower the cable supports. Check that the "UP" and "Down" lights illuminate.

NOTE: It may be necessary to cycle the system once or twice to fill the system in order for all the supports to react at the same time.

(c) Insure that the cable supports cannot be activated from the runway edge control box while the Tower/Runway switch is in the "Tower" position.

(d) Place the Tower/Runway switch in the "Runway" position. The red Runway Permissive lights should illuminate on the tower control box, and the green Runway Control light should illuminate on the runway edge control box.

(e) Activate the BAK-14 system. Record the time required to raise and lower the cable supports. Check that the "Up" and "Down" lights illuminate.

(f) Place the Up/Down switch on the tower control box in the opposite position from that on the runway edge control box.

(g) Return the Tower/Runway switch to the "Tower" position. The cable supports should react as directed by the tower control box. The red Runway Permissive and green Runway Control lights are not illuminated.

Phase III - Dynamic Tests: Dynamic tests are required to evaluate the performance of the BAK-14 Retractable Cable Support System. Existing weather conditions will prevail.

1. The cable supports will be cycled 100 times to verify the system reliability. Fifty of these cycles will be originated at the tower control box and the remainder will be initiated at the runway edge control box.

2. The BAK-14 system will be subjected to total of 12 rollovers by the main landing gear of an F-4E aircraft. The rollover tests will be as follows:

(a) One rollover with the main landing gear passing between the cable supports will be conducted at taxi velocities of 60, 80, and 100 knots.

(b) A total of 9 rollovers (or until 3 supports have failed) with the main landing gear impacting a support will be conducted at a taxi velocity of 100 knots.

3. The BAK-14 system will be subjected to a total of 6 aircraft hook arrestments.

(a) One hook arrestment, with the hook passing between two supports, will be conducted at taxi velocities of 60, 80, and 100 knots.

(b) One support will be impacted by the hook of the F-4E aircraft at a taxi velocity of 100 knots until failure or a total of 3 hook impacts.

4. The aircraft pilot will determine flight operating conditions, minimum landing criteria (OPNAV3710.7G) and safe runway conditions. It will be the aircraft pilot's discretion to brake, arrest, or take-off in case of a missed engagement or equipment failure.

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5. The following information will be required for each rollover and hook arrestment:

(a) Aircraft indicated air speed

(b) Wind velocity and direction

(c) Ambient temperature--this will also be required during the cycle tests of the cable supports.

(d) Aircraft weight

(e) Condition of the cable supports

(f) Any difficulties encountered in placing the cable in the support blocks or tying the cable down.

6. After the above tests or after a support block has failed, the procedure for installing a new support block will be evaluated.

PHOTOGRAPHIC COVERAGE

1. Still photographs will be required of any equipment failure or possible problem areas.

2. Two high-speed motion picture cameras will be required to cover BAK-14 components as requested by the test director. These cameras will operate under limited light conditions, and at approximately 100 frames per second due to the weather conditions.

PARTICIPANT RESPONSIBILITIES

1. The Naval Air Test Facility will be responsible for directing the tests, piloting the aircraft, and accident and incident reporting in accordance with reference (c).

2. The Naval Air Engineering Center will monitor the tests.

3. The United States Air Force will be responsible for the following:

(a) Providing and maintaining the aircraft.

(b) Providing billets, local climatic indoctrination, and weather clothing for USN personnel.

(c) Briefing the USN pilot on local area flight procedures.

(d) Operating, maintaining, and supporting the BAK-14 and BAK-12 systems.

(e) Providing communications between the test team and the aircraft pilot.

(f) A temporary shelter near the test site for USN personnel.